Department of Scientific and Industrial Research
and Fire Offices' Committee
Joint Fire Research Organization

# *Effect of draughts on the burning of portable oil heaters*

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# PREFACE

FOLLOWING a fire at Ware, Herts, on the 13th November, 1959, it was discovered that drip-feed radiant oil heaters could give rise to serious fires when operated in draughts commonly encountered in dwellings. This report deals with the effect of draughts on the operation of this type of heater, and an examination has been made of its likely performance in dwellings. Suggestions are made both for the improvement of the future design of such heaters, and for the modification of some existing models to render them less susceptible to draughts.

Acknowledgment must be made of the help received from Social Surveys (Gallup Poll) Ltd., who gave freely of their services and enabled figures for the number of oil heaters in use to be obtained.

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FIRE RESEARCH STATION,
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*February*, 1960.

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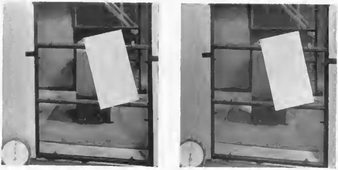
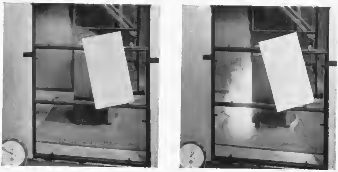


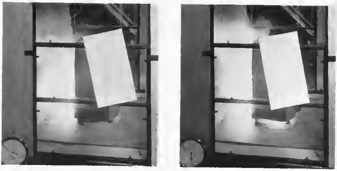
(a) on application of draught

(b) after 30 s



(c) after 49 s

(d) after 65 s



(e) after 78 s

(f) after 90 s

PLATE 1.

PERFORMANCE OF TYPICAL HEATER IN DRAUGHT OF 5 FT/S

# EFFECT OF DRAUGHTS ON THE BURNING OF PORTABLE OIL HEATERS

## INTRODUCTION

THIS REPORT deals specifically with the hazards of oil (kerosine, paraffin) heaters of the drip-feed radiant type when operated in draughts. There are, no doubt, other dangers associated with the operation of heaters in which the head of fuel is above the burner, but these are outside the scope of this report and are at present being considered by a Committee of the British Standards Institution on which the industry is represented.

The investigations described in this report were initiated as a result of the fire at Ware on the 13th November, 1959, in which five children lost their lives. The fire was attributed to a portable oil heater (of the radiant type) and evidence given by the Director of Fire Research at the subsequent inquest showed that heaters of this type could give rise to serious fires if exposed to draughts. The way in which this occurs may best be understood by reference to Fig. 1, which shows diagrammatically a typical heater. The kerosine in the fuel tank A passes into the fuel dish D through a spring-loaded valve B which is kept open by the filter C while the tank is in position in the heater. The fuel thus flows from the tank until the level of the fuel in the dish covers the outlet of the spring-loaded valve, after which the supply ceases until some of the fuel is consumed, causing the level in the dish to fall. The principle is similar to that of the well-known chicken fountain. The dish D is connected through a regulator valve to the kindler wick chamber. The heater is started by lighting the kindler. The burner consists of two concentric perforated cylinders E and F with an outer cylinder G surmounted by a gauze dome H. When the burner has warmed up after ignition, combustion then takes place in the space between the inner sleeves E and F and in the space just above them, so that the gauze dome becomes incandescent; the radiant heat thus produced is projected into the room by a polished reflector (not shown in diagram). The burner is normally separated from the fuel tank by a screen which in some cases extends down to the base plate of the heater.

When the heater is exposed to a draught, the radiant dome is cooled and, if the draught is sufficiently strong, the burning is transferred to the base of the front compartment of the heater within about 30 seconds. The flames spread to the rear compartment containing the fuel tank, heating the air and kerosine vapour above the kerosine so that kerosine is expelled from the tank, drips from the heater and ignites. The sequence of events is shown in Plate 1.

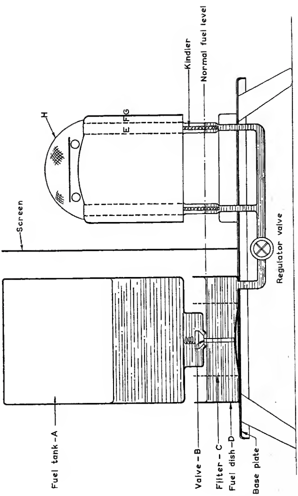


FIG. 1. *Diagram of Oil Heater*

The initial tests were confined to the one make of heater, but it was obvious that the hazard could exist in all heaters of this general type. The Director of Fire Research therefore wrote on the 26th November to all the known manufacturers requesting that, as a matter of urgency, samples of their heaters be sent to the Fire Research Station so that their performance could be tested under conditions of draught. All the manufacturers agreed to co-operate and have shown a continuing interest throughout the investigation.

The hazard due to draughts on oil heaters depends on two main factors:

i. The effect of draughts of different rates on the behaviour of the range of oil heaters in use.

ii. The probability and frequency of any given rate of draught under normal conditions in domestic dwellings.

This report describes the work on these two aspects of the main problem, together with the general conclusions to be drawn.

## FIRES ATTRIBUTED TO PORTABLE OIL HEATERS

Before describing the experimental work, it may be helpful to give some figures for the number of fires due to portable oil heaters in relation to the number at risk. Unfortunately, the statistics available at present do not permit a statement to be made on the number of fires caused by different types (i.e., convector, radiant, etc.). The number of fires due to oil heaters as a whole has increased with the growing popularity of this type of heating, and the rate of incidence per 1,000 tons of kerosine used for domestic purposes increased from 2·2 to 4·1 from 1947 to 1955 and since that date has remained fairly constant at the higher level. The number of fires caused by oil heaters of all kinds has increased from 1,340 in 1947 to 4,464 in 1958. In 1956, 32 fatal casualties were caused by oil fires in dwellings, the total number of such fires being 1,202. A detailed analysis was made in 1956 and showed that of these 1,202 fires, 1,075 were due to portable heaters. Of these, 246 were ascribed to overheating or flaring. From the number of cases in which the type of heater was known there was no evidence at that time that the radiant type of heater was particularly prone to overheating or flaring, although it appeared to be much more liable to leaking or flooding (30 per cent of incidents as compared with 10 per cent for other types) and in the light of subsequent experience it now appears that some of these latter incidents could have been caused by draughts.

In order to help the present investigation Social Surveys (Gallup Poll) Ltd. undertook, as a matter of urgency, a pilot survey to ascertain the number of oil heaters in use in Great Britain, and from this it would appear that the total number of portable oil heaters is about ten million, of which some three million are of the type referred to in this report.

## TESTS OF HEATERS IN DRAUGHTS

All the manufacturers who were approached submitted samples of their current production for test—35 models in all. One model supplied had the fuel tank below the burner, which was fed by a wick. As it was not of the drip-feed type under consideration in this report, the results of tests on this heater have been omitted. In addition five improved models were submitted in which modifications had been made to reduce the hazard due to draughts.

The heaters were tested for their behaviour in draughts in:

i. A small wind tunnel specifically built for these tests with a cross section at the testing zone of 16 ft$^2$ and

ii. The large wind-producing apparatus, developed by the Joint Fire Research Organization for work on fires in models, with a cross section of 150 ft². This has a range of wind speeds 0-30 mile/h (0-44 ft/s) and was used for tests involving wind speeds in excess of 3·3 mile/h or 5 ft/s.

The test was carried out as follows: The fuel tank was half-filled with a typical premium-grade kerosine, having a flash point of 122°F, obtained directly from a bulk distributor. The heater was then prepared for lighting in the way prescribed by the manufacturers for maximum heat output and allowed to burn for at least 15 minutes. The heater was tested in four positions, viz.:

i. The front of the heater facing the draught.

ii. With the draught at 60° to the face of the heater.

iii. With the draught at 60° to the face of the heater but from the other quarter.

iv. The back of the heater facing the draught.

The performance of the heater quoted in the following results is that corresponding to the worst obtained at any given draught speed regardless of its direction.

## CLASSIFICATION OF RESULTS

From visual observations of the tests, the behaviour of the heaters could be divided into five categories as follows:

(a) Little or no disturbance of the flame.

(b) Flaring above the radiant dome of the heater, but *not* extending outside the guard.

(c) Flaring above the radiant dome extending outside the guard.

(d) Displacement of the flame, resulting in flaring at the base of the short drum burner and outside the body of the heater, but not so as to involve the fuel tank compartment of the heater in the test period (60 seconds). This period was chosen to avoid undue damage to the heater while the series of tests were in progress.

(e) Flaring at the base, with the flame penetrating into the fuel compartment in less than 60 seconds.

The first two categories may be regarded as reasonably safe. It should be mentioned here that, in regarding as safe heaters which may give rise to slight flaring, no account has been taken of the requirements of B.S. 2049 for guards for fires and it is possible that the flaring might ignite the flannelette used in the test in that Standard. Presumably, however, the test in that Standard would be applied in normal conditions and under conditions of draught the flaring is so erratic that it would be difficult to get valid results. The last three categories are hazardous in increasing order of severity; (e) will result in rapid development of fire due to flooding of the kerosine over the floor as outlined in the introduction to this report, and (d) will usually result in penetration of flame into the compartment containing the fuel tank, after a longer period than that specified in (e).

The initial tests were carried out at a daught speed (arbitrarily chosen) of 5 ft/s or 3·3 mile/h. Heaters appearing safe (categories (a) and (b)) at this draught speed were then tested at higher draught speeds until they became hazardous. Those appearing hazardous (categories (c)-(e)) were tested at lower draught speeds down to 1·4 ft/s, a little under 1 mile/h, or until they appeared to be safe.

The results for the production models and for the improved models are shown separately in Table 1 (A) and (B). In view of the urgency with which these results were required it was necessary to restrict the work to the minimum required for assessment of the practical hazard. Heaters were not always tested at a speed above which they were placed in category (d) or (e) or below that at which they were reasonably safe (category (a) or (b)). It is therefore assumed in this Table that:

i. If a heater is safe at any given draught speed it will also be safe at a lower draught speed.

ii. If a heater is dangerous at a given draught speed it will also be dangerous at a higher draught speed.

Since both (a) and (b) are relatively safe, these have been combined in the Table below; (d) and (e) have been similarly combined, both being of great hazard.

*TABLE 1*

*Effects of draughts on heaters*

(A) Production models (34 samples):

| Draught speed | | Number of heaters | | |
|---|---|---|---|---|
| | | Category of performance | | |
| ft/s | mile/h | (a) and (b) | (c) | (d) and (e) |
| 10 | 6·7 | 0 | 0 | 34 |
| 5 | 3·3 | 2 | 0 | 32 |
| 3·2 | 2·1 | 8 | 2 | 24 |
| 2·5 | 1·7 | 27 | 6 | 1 |
| 1·4 | 0·9 | 32 | 2 | 0 |

(B) Improved models (5 samples):

| Draught speed | | Number of heaters | | |
|---|---|---|---|---|
| | | Category of performance | | |
| ft/s | mile/h | (a) and (b) | (c) | (d) and (e) |
| 10 | 6·7 | 1 | 0 | 4 |
| 5 | 3·3 | 4 | 0 | 1 |
| 3·2 | 2·1 | 5 | 0 | 0 |
| 2·5 | 1·7 | 5 | 0 | 0 |

The effect of fluctuating draughts has been considered and the fluctuations do not in themselves appear to affect the performance of the heater apart from some increase in flaming above the radiant gauze. The general performance appears to be controlled by the peak draught speed.

The results show that:

i. Nearly all of the heaters now in production present a severe hazard in a draught of 5 ft/s or above.

ii. Most of the heaters do not show this hazard in a draught of less than 3·2 ft/s and all were reasonably safe in one of 1·4 ft/s with the exception of two which were still in category (c).

iii. The improved models in which quite simple modifications had been made were in general less hazardous than the original models; this indicates that it is possible to reduce the hazard by practicable modifications in design.

### THEORETICAL EFFECT OF DRAUGHTS ON COMBUSTION

It was stated earlier that the combustion in the short drum burner takes place between two perforated concentric cylinders; in operation these attain a temperature (obtained by experiment) of 600°C.

From energy considerations it might be expected that the burning would be disturbed by a down draught of the order of $\sqrt{\frac{2gh(T_1-T_0)}{T_1}}$ where $T_0$ is the absolute ambient temperature, and $T_1$ and $h$ the absolute temperature and height of the cylinders respectively. This neglects the effect of the hot-gas column above the cylinders and the effect of the entrainment of air through the perforations. These two factors work in opposite directions. On substituting numerical values, a down draught of the order of 4 ft/s would be expected to interfere with the flame.

## SURVEY OF POSSIBLE DRAUGHTS IN HOUSES

Having determined the performance of oil heaters in draughts over a range of speeds, it is necessary to investigate the likelihood of such draughts being encountered in dwellings. This will depend on a number of factors including the external wind speed, the orientation of the house with respect to the wind, the geometry of the house and the degree of ventilation.

### EXTERNAL WIND

An outline of the probable pattern of the external winds prevailing during the normal heating season has been obtained by calculating the frequency distribution of winds of various speeds during the autumn and winter. The calculations were based on data published by the Meteorological Office, and the results are shown in Fig. 2; these have been used in interpreting the results described later.

### INTERNAL DRAUGHTS

Investigations have been made to determine the magnitude of the draughts occurring near floor level in domestic dwellings. Two series of tests have been carried out: the first consisted of determinations, under controlled conditions, of the draughts occurring in a full-scale experimental room exposed to external winds over a range of wind speeds of 4-34 ft/s. The second was a limited survey of the draughts occurring in a number of occupied dwellings,

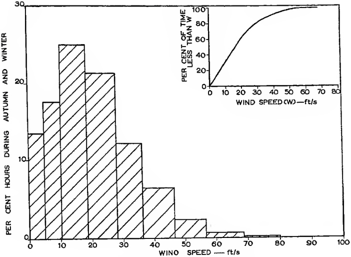


FIG. 2. *Wind Speed Frequency Chart*

## EXPERIMENTAL ROOM TESTS

For these tests a structure was erected consisting of a full-scale room together with adjoining hall and stairway (Fig. 3). This was fairly typical of a local authority dwelling. The flue aperture in the fireplace was represented by a slot aperture 3 in. by 10 in. situated above the floor and was connected to an external flue. This room was not furnished; massive pieces of furniture extending to floor level would obviously affect the flow pattern, but it is not thought that in most cases they would affect the strength of the draught. The structure was built on a raft in the wind apparatus section of the Models Laboratory so arranged that it could be rotated to face in any direction relative to the incident wind.

Tests were made with incident wind velocities up to 34 ft/s (23 mile/h) with the house in two positions so that the two directions of the incident wind were as shown in Fig. 3. The draught speeds in the house were measured 1 ft above the floor at points A-F. Experiments were made both with doors fully opened and closed and in some tests with an opening in the staircase cover to simulate the effect of open windows on the first floor; otherwise the windows were closed.

The results have been grouped into two sets. Table 2 gives those obtained with exterior doors and windows closed. Under these conditions, which may be considered normal when heating systems are used, the draught speeds were low and in the room were considerably less than 1 ft/s.

Table 3 gives the results obtained with the front door and, in some cases, other doors, open. The draught speeds were naturally much higher, notably in certain positions such as near the front and back walls of the room, near the fireplace and in the hall. Though the hall in this case was so small that it was most improbable that a heater would be placed there, it should be noted that strong draughts will be encountered in halls and passages between doors leading to the exterior.

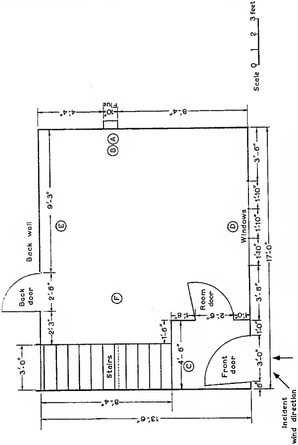


FIG. 3. *Ground Floor Plan of Experimental Room*

## SURVEY IN DOMESTIC DWELLINGS

The results in Tables 2 and 3 have been supplemented by measurements carried out by the staff of the Joint Fire Research Organization in their own houses during the month of January in various test positions. This was, of necessity, a limited survey and only involved exterior winds of up to 16 ft/s. Under these conditions with all the exterior doors closed, the interior draught speed never exceeded 0·7 ft/s. Under more severe conditions, with external doors open, the draught speeds were higher as might be expected. In particular with two external doors open, draught speeds as high as two-thirds of the external wind speed were measured in positions in which an oil heater might be placed. With one external door open, the draughts tended to be smaller and roughly one-third of the external wind speed would be a fair average.

*TABLE* 2

*Draught measurements with exterior doors and windows closed*

| Condition of doors and stair cover | Incident wind speed ft/s | Draught measurements in ft/s at: 6 in. in front of flue opening (A) | 1 ft in front of flue opening (B) | Foot of stairway (C) | Below windows on front wall (D) | Centre of rear wall (E) | Between room and back door (F) |
|---|---|---|---|---|---|---|---|
| Incident wind perpendicular to front elevation | | | | | | | |
| Front, room and back doors closed. Stair cover closed | 15 | 0·2 | 0·1 | 0·3 | 0·1 | 0·2 | <0·1 |
| Incident wind at 45° to front elevation | | | | | | | |
| Front, room and back doors closed. Stair cover closed | 16 | 0·4 | 0·2 | <0·1 | <0·1 | 0·3 | <0·1 |

*TABLE* 3

*Draught measurements with exterior doors open and windows closed*

| Condition of doors and stair cover (Door and stair cover closed unless otherwise stated) | Incident wind speed ft/s | Draught measurements in ft/s at: 6 in. in front of flue opening (A) | 1 ft in front of flue opening (B) | Foot of stairway (C) | Below windows on front wall (D) | Centre of rear wall (E) | Between room and back door (F) |
|---|---|---|---|---|---|---|---|
| Incident wind perpendicular to front elevation | | | | | | | |
| Front door open | 15 | 0·4 | 0·1 | 2·2 | 0·7 | 0·4 | 0·1 |
| Front and room doors open | 27 | 2·1 | 1·2 | 6·1 | 2·0 | 1·0 | <0·1 |
| Front and room doors open. Stair cover open | 28 | 1·5 | 0·3 | 21 | 1·5 | 2·0 | <0·1 |

*Table* 3 (continued)

Incident wind perpendicular to front elevation (continued)

| Condition of doors and stair cover (Door and stair cover closed unless otherwise stated) | Incident wind speed ft/s | Draught measurements in ft/s at: 6 in. in front of flue opening (A) | 1 ft in front of flue opening (B) | Foot of stairway (C) | Below windows on front wall (D) | Centre of rear wall (E) | Between room and back door (F) |
|---|---|---|---|---|---|---|---|
| Front, room and back doors open | 25 | 3·3 | 1·7 | 11 | 21 | 11 | 2·5 |
|  | 13 | 1·7 | 1·0 | 8·4 | 12 | 6·9 | 1·0 |
|  | 7·0 | 0·7 | 0·5 | 6·8 | 6·8 | 5·8 | 0·5 |
| Incident wind at 45° to front elevation |  |  |  |  |  |  |  |
| Front door open | 16 | 0·6 | 0·3 | 0·9 | 0·2 | 0·2 | <0·1 |
| Front and room doors open | 29 | 5·0 | 2·8 | <0·1 | 3·7 | 3·3 | <0·1 |
| Front and room doors open. Stair cover open | 16 | 3·0 | 1·7 | 2·3 | 1·7 | 0·8 | <0·1 |
|  | 11 | 1·3 | 1·0 | 0·8 | 1·0 | <0·1 | <0·1 |
| Front, room and back doors open | 34 | 10 | 8·3 | 1·0 | 10 | 9·4 | 21 |
|  | 21 | 6·0 | 2·6 | 2·5 | 6·7 | 5·0 | 11 |
|  | 14 | 1·2 | 1·3 | 1·7 | 3·3 | 1·7 | 8·0 |

The question now arises of relating the above results to wind speeds commonly encountered in this country. It will be seen from Fig. 2 that a wind speed exceeding 36 ft/s will occur for only 10 per cent of the total time and this figure has been arbitrarily chosen as the upper limit of the wind speeds which may occur. Wind speeds in excess of this will be encountered but it must be borne in mind that the wind will not always be in such a direction as to cause strong interior draughts and it is assumed that, at such high wind speeds, more than usual care will be taken to keep exterior doors closed for reasons of personal comfort.

In the tests on the full-scale model with one or more exterior doors open, draughts of 21 ft/s were encountered in two positions with exterior wind speeds of 34 and 25 ft/s. Extrapolating to an external wind speed of 36 ft/s would suggest that the highest draught corresponding to this exterior wind speed would be of the order of 25 ft/s. In closed rooms, the draughts observed were less than 1 ft/s and are unlikely to exceed this by very much even for wind speeds up to 36 ft/s.

It is impossible, however, to neglect the fact that on some occasions, and admittedly mainly for short periods, exterior doors may be left open. Under these conditions, draughts may be much greater and may attain speeds of the order of 25 ft/s.

## REMEDIAL MEASURES

### DANGEROUS DESIGN FEATURES

Draughts incident on the heater are deflected downwards by the hooded reflector which is frequently in the form of a section of a sphere and extends over the burner. The down draught is also accentuated if the front of the burner compartment is closed or, even worse, if the compartment is ventilated by holes or louvres in the base which face away from the incident draught.

The screen between the burner and fuel compartments does not always extend to the base plate so as to form a complete barrier between them, and thus any flames from the base of the burner can readily penetrate into the fuel compartment, heat the container and cause the kerosine to overflow.

## POSSIBLE REMEDIAL MEASURES

In addition to avoiding the bad design features mentioned above, certain measures may be adopted to stabilize the burning of the heater. These are directed towards raising the pressure at the base of the burner to prevent the flames being blown down on to the kindler. The following measures will all tend to stabilize the burning:

1. An extra cylindrical sleeve, fitted over the outside of the burner sleeve G (Fig. 1) and faired to the shape of the reflector, will collect any down draught from the reflector and conduct it to the base of the combustion chamber. The junction between the base plate and the extra cylinder should be sealed and the base plate within the cylinder should not be perforated. A simple device of this type is surprisingly effective and has been shown to give safe operation in draughts up to the highest test speed (26 ft/s).
2. The base of the heater should preferably not be perforated. As heaters are relatively immune from draughts coming from behind, any louvres that are in the base should face the front of the heater.
3. Another possible way of stabilizing the burning would be to fit a cylindrical extension above the gauze so as to decrease the pressure at this point, but as this extension would partially obscure the radiant heat, it might not be popular.
4. The effect of the down draught is controlled by the height of the burner and therefore, by lengthening this, heaters could be made less susceptible to draughts.
5. A covered overflow vessel should be incorporated, of sufficient capacity to contain the maximum volume of fuel in the heater.

## HEATERS ALREADY SUPPLIED TO THE PUBLIC

It is estimated that there are about three million heaters already in use of the drip-feed radiant type. These will operate satisfactorily in houses with the exterior doors closed under practically all conditions, provided there are no excessive draughts from windows. When exterior doors are opened, particularly if a strong wind is blowing, there is a risk that a serious fire will start, involving the fuel contents of the heater.

Any remedial measure must be simple in the extreme, such as an attachment which could be sold cheaply and fitted at home or by a local dealer. This rules out any mechanical work. A possible modification (though not necessarily the only one), has been tested and has been described in the previous section. This would necessitate the provision of a sleeve which could be slipped over the existing burner. Any holes in the base within the sleeve should be plugged.